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The Study of Pedestrian Accessibility to Rail Transit Stations Based on KLP Model

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Abstract

In order to study the travel range of the pedestrian choice of rail transit, this paper analyzed factors influencing the choice of walking access mode, by conducting simulated experiments and questionnaires investigation. Based on Kishi's Logit Price Sensitivity Meter (KLP) model, a method for calculating the distance and time threshold of pedestrians' access to urban rail stations was presented. It also drew some conclusions that the standard walking access distance is 472 meters and the maximum value is 862 meters, from the point of pedestrians' willingness. Furthermore, the ideal access time and maximum acceptable time is 8.1 minutes by 50th percentile and 16.3 minutes by 85th percentile, respectively. The paper made a comparative analysis about the distribution features of pedestrian distance and time acceptability and the differences between the feel accuracy of time and distance for individuals. In addition, these differences were further used to revise the space- time threshold values.

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Keywords: Railway Transit;Travel psychology;Pedestrian access;KLP;Access threshold;

1.INTRODUCTION

With the advocacy of the "Transit City", Green travel and Low Carbon travel have become the goals of urban transport development. Walking as the most important traffic access mode of the bus system front-end and back-end has gradually been taken seriously. The transfer mode of Pedestrian & Rail Transit is also considered to be

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the best example of the traffic integration and green transportation travel. It is not only a low-carbon, green and sustainable transport operating mode, but also one of the effective ways to alleviate the urban traffic congestion.

Walking distance and walking time is important factors to influence people whether or not to choose public transport, especially in the area of large residential areas or urban non-central living areas. A large proportion of residents' commuting and school travel depends on the walking access to the transit stations. The straight-line distance from home to urban rail transit stations can also directly reflects the influence of the urban rail transit and service areas around transit stations. Due to the physical, psychological, and other reasons, pedestrians would have a certain tolerate limits of walking time and distance. Once beyond this limit, they would change their travel behavior. This tolerance on distance and time is called space-time threshold, which can be further subdivided into the ideal threshold value and acceptable limit threshold value (Xiong Wen, 2008).

2.LITERATURE ON WALKING ACCESSIBILITY TO TRANSIT STATIONS

The traffic survey of Beijing residents in 2005 shows that walking is the most frequently used mode of accessing before going to and going out of the rail stations, which are 66.26% and 74.65% (Liu Lina, 2010) respectively. Wang Hongwen's (2012) survey shows that the urban rail transit mainly attracts passenger flow by walking (i.e. directly attract), accounting for more than 70%, besides conventional public traffic accounted for 23%, and bicycle was 3%. According to the survey data, the average time consumption of walking access mode is about 10min, therefore a reasonable walking area of the rail transit stations for the area round about 660 meters of distance. Zhang Ning, Dai Jie and Zhang Xiaojun (2012) suggested that the walking environment, individual characteristics, and other related factors would have a great impact on average walking time for pedestrian accessibility to transit stations. Considering factors of means of transportation and road walking environment, the author developed the multinomial Logit travel mode choice model, and thus figured out the walking time using the utility equality of travel mode. Finally, the author discovered that the walking access of residents around transit stations is 904 meters and the maximum acceptable time 16.5 minutes.

The study on walking accessibility to rail transit is more popular in foreign countries than that in China. Dennis Zielstra (2011) mentioned that the walking distance to transit stations is 400 meters (0.25 miles) and 800 meters (0.5 miles) for rail stations with most passengers (75-80%). A more recent study suggests that a larger catchment area around transit stations, with an 85th percentile of walking distances to bus service of around 550 meters from the origin and 615 meters to the destination. For metro service, distances were found to be 750 and 695 meters, and for light rail 1 200 and 1 100 meters, respectively. Ahmed M (2012) used distance decay curves as a means of understanding service areas. Sungjin Park (2008) discovered that the three most important factors are walking distance, car availability and gender in the choice of whether or not choosing walking access rail transit station.

Compared with the researches in China, other countries' study on walking to rail transportation is based on population density, regional policy, as well as travel habits. All of these researches are significant for further study, although there are some differences between individuals and environment. The study on space-time threshold of walking access to rail stations for China's population characteristics still needs more researches and there is a lack of study considering traveler psychology willingness and perception.

This paper presents our work on the distribution features of pedestrians' distance acceptability and time acceptability to rail stations access, threshold of walking access to rail stations and so on. The research can provide more humane indicators for reasonable planning and designing of walking facilities surrounding rail transit stations.

3.DATA ACQUISITION AND ANALYSIS

3.1 Survey Overview

The data collection methods include questionnaire survey and field simulation experiment. Questionnaire survey is divided into Revealed Preference (RP) and Stated Preference (SP), which was carried out on September 14, 2012, with 132 effective questionnaires collected. The field simulation experiment was conducted on the morning of September 20, 2012, around a university in Beijing, when the weather is fine.

The main content of this survey: 1) personal attributes, including age, gender, occupation, trip purpose, access paths familiarity, etc; 2) travel behavior, including the origin and destination of access path, the willingness of connection distance (containing ideal value、acceptable value and the maximum limit value), based on KLP's principle， etc.

3.2 Personal Attributes

The main subject in the questionnaire survey was the rail commuter group, whose age was mainly distributed between 18 to 35 years old, and the proportion of male and female were 55% and 45%, respectively. The travel purpose basically was to go to school or work. The subjects of field walking experiments were student groups, who were familiar with the surrounding environment of the simulation scene.

3.3 The Factors Influencing Urban Rail Transit Passengers Access Behavior

(1)Analysis of factors influencing access mode choice

Factors were rated by respondents on a scale graded in five semantic levels to estimate the degree of importance when influencing the choice of urban rail transit passenger access mode (shown in Figure 1.). Respondents were asked to what extent a factor was considered important to them among these following values: very important; somewhat important; a little importance; little importance; not at all. Passengers are most concerned about the distance to the subway station among the factors affecting the access modes of rail passengers. 67% of them thought it was very important, 27% of them believed it was somewhat important. The second most influencing factor is whether detour, the frequency and degree of difficulty of crossing the street and road congestion level, and half of them thought very important. The greater impact of climate and weather conditions accounted for 41%. For sidewalk obstacles and woods shading rates, the impact degree of which is little or very little. Roadside landscape and roadside architectural style have no or little impact on the choice of urban rail transit access mode.

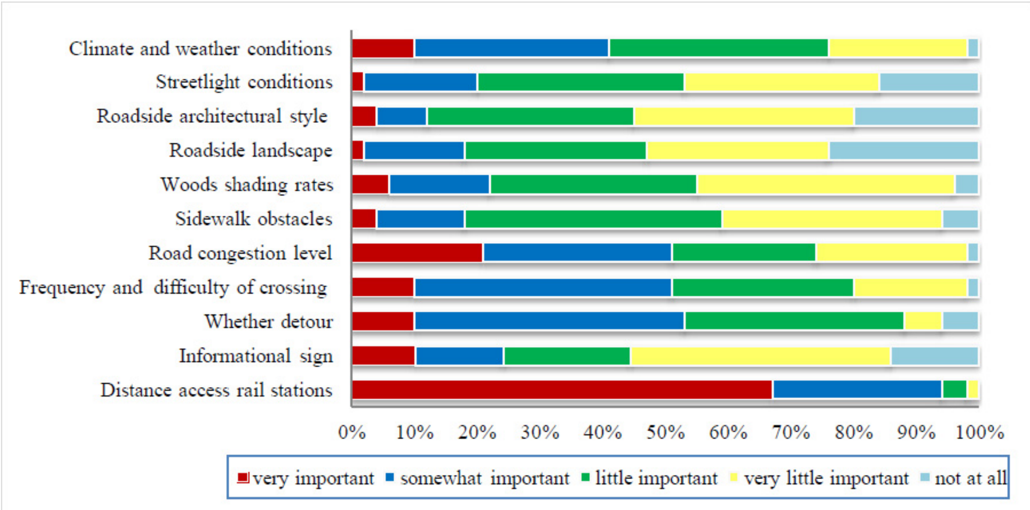

Figure 1 Factors influencing the choice of urban rail transit passengers access mode

(2)The analysis of factors influencing whether choose walking as an access mode to urban transit

For people walking to subway stations, the walking distance to the stations is the most important factor. The survey results showed that 84% of them thought the distance was very important and respondents who chose somewhat important accounted for 16%.

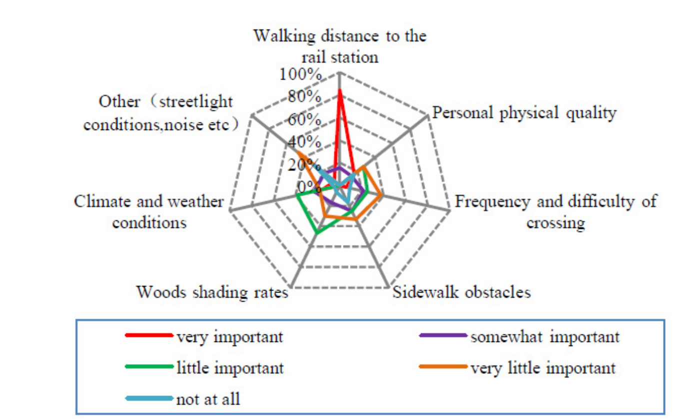

Figure 2 Factors influencing passengers choose walking as access mode

4.THE SPACE-TIME THRESHOLD OF WALKING ACCESS TO RAIL STATION

4.1 Kishi's Logit PSM，KLP

KLP is developed on the basis of Price Sensitivity Measurement (PSM). Price Sensitivity Measurement (PSM) is a method to measure consumers' perceptions of price for a product or a brand, which is used to subdivide consumer price feelings. In the PSM method, consumers are asked to provide feelings about product price at four different levels: “reasonable,” “expensive,” “too expensive to be willing to buy,” and “too cheap to be willing to buy. The frequency of each question on a different price point is calculated. Based on the collected data, frequency distributions were analyzed and relative cumulative frequency curves were established as shown in figure 3. Curve crossing point is the price threshold point, and eventually we can get an acceptable price range, the optimal price point and no-difference price point (Kishi, K., Uchida, K., and Satoh, K., 1999). However, we cannot make detailed evaluations in PSM on the price range that is not included in the subjects’ responses. Kishi’s Logit PSM (KLP) has improved PSM through applying four relative cumulative frequencies that are regressed by using the logit model as indicated by equation (1) and equation (2). The resulting curves are shown in Figure 3. When a dependent variable lies between 0 and 1, it is equal to the relative cumulative frequency. As the logit model is a continuous function, KLP can circumstantially analyze consumers’ evaluation on any prices.

$$T = \frac{1}{1+\exp F(x)} \quad (1)$$

$$F(x) = ax + b \quad (2)$$

Where, T: relative cumulative frequency; x: price (here is distance); T_1，F_1: should be less expensive; T_2，F_2: should be more expensive; T_3，F_3: too expensive to be willing to buy; T_4，F_4: too cheap to be willing to buy.

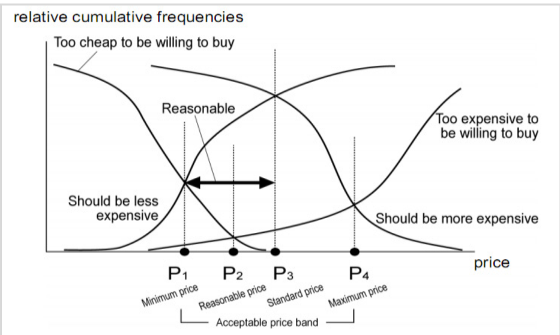

Figure 3 KLP principle diagram

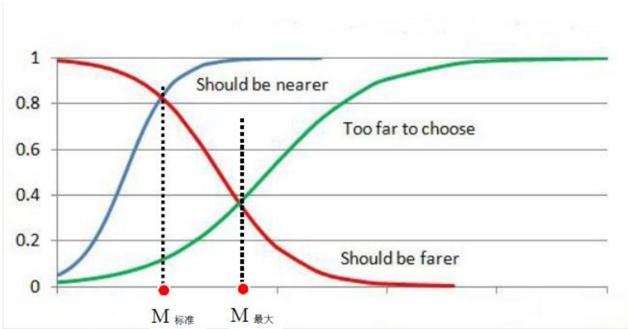

Figure 4 Application of KLP for rail access behavior

KLP has been used to analyse location planning of elevators at subway stations considering transfer resistances (Kishi, K., Hino, S. and Satoh, K., 2003).It also evaluates the reasonable transfer distance at urban rail stations (He Jing, Liu Zhigan and Sun Youwang, 2010). Similarly, KLP has been applied to the rail connection behavior analysis to quantize mental acceptability limit of walking distance and time to urban rail stations. For people who walk to rail transit stations, less distance and time is better, and therefore the key of the study is to find out the ideal and longest distance people can bear. Here the distance is equivalent to the price, as "far, near" being the "expensive, cheap" and "choose walking as feeder mode" being "to buy".

Generally speaking, it is difficult to quantify pedestrians’ psychological feeling about the access distance and time they would bear. However, it has been found that the problem of space-time threshold value has similarity to the issue of determining the commodity prices. Therefore, Kishi’s Logit PSM (KLP) was applied for quantification of the conscious distance and time rage that pedestrian can bear.

Considering the fact that pedestrians who think distance too close to choose walking actually do not exist, we can get three distance and cumulative frequency related functions and curves ,using the data collected to calibrate the model,. From figure 4, curve intersections can also be obtained and is called the distance threshold point. It can be seen that the standard distance means the distance the pedestrians think such interchange distance is neither near nor far. That is to say, normally, this distance will be a boundary which is used to measure the reasonable distance. For maximum distance, if the interchange distance exceeds the ideal distance, most of the pedestrians would feel it too far to walk. And, their psychological burden will increase. So we regard the maximum distance as the limit of the consciousness resistance.

4.2 Application of KLP to Analysis of the Space-time Threshold of Walking Access to Rail Stations

As can be seen from the previous survey, Pedestrian& Rail Transit is most concerned about the distance or time to the rail station. The determination of the space-time threshold of access to urban rail stations can be used as an important basis for evaluation of land layout around urban rail stations and its scale. The space-time threshold will be calculated and analyzed, respectively, as follows.

(1)Distance Threshold

The KLP model has been calibrated based on questionnaire data (all samples). Finally, the results are presented in formulas (3) to (6), and continuous curves are shown in figure 5. Table 2 shows the results from analysis of KLP.

$$T = \frac{1}{1+\exp F(x)} \tag{3}$$

$$T_1; \quad F_1 = -0.009\,7x + 3.018\,5 \qquad (R^2 = 0.817) \tag{4}$$

$$T_2; \quad F_2 = 0.006x - 4.399\,4 \qquad (R^2 = 0.97) \tag{5}$$

$$T_3; \quad F_3 = -0.004\,2x + 4.027\,6 \qquad (R^2 = 0.92) \tag{6}$$

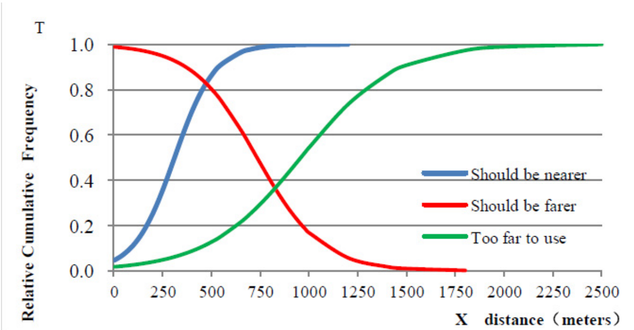

Figure 5 Analysis for threshold value of walking distance to transit stations

The standard distance 472 m refers to the distance that the pedestrians think is neither near nor far, which is reasonable. That is to say, normally, this distance will be a boundary which is used to measure the distance. The meaning of maximum distance 862 m is that if the interchange distance exceeds the distance, most of the pedestrians would feel too far. And their psychological burden would increase. So we regard the maximum distance as the limit of the consciousness resistance.

Table 1. The result of walking distance threshold value by KLP method

（meters）

Category	Standard distance	Maximum distance
All samples	472	862
Male	450	798
Female	466	840

(2)Time Threshold

The disaggregate model regression for male and female's connection time acceptability degree distribution curve (Fig. 6[a] and6[b]).

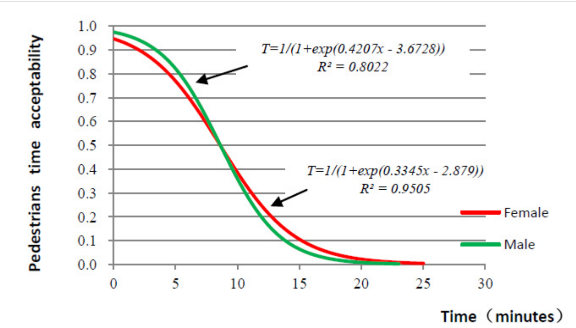

Figure 6[a] The distribution of the ideal walking access time

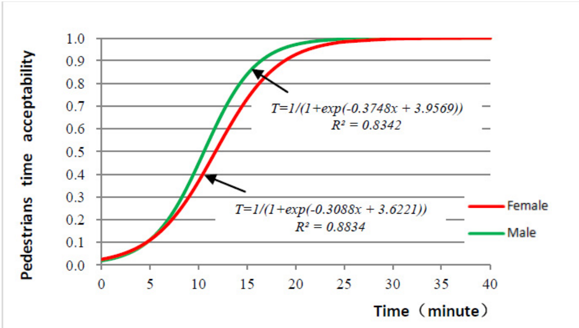

Figure 6[b] The distribution of the maximum wailing access time

In curve 6[a], at the 50% quartile, the ideal access time for male and female is 8.5minutes and 8.7minutes, respectively. After the time of 9.2 minutes, female has greater acceptability than male does. The possible reason is that the tolerance degree of females is greater than that of males, and a maximum female value can be as long as 25 minutes. In curve 6[b], at the 90% quartile, men can accept the maximum time of about 16.4 min, and women can accept 18.8 min. In the same way, it may be the reason that females' tolerance degree greater than males'.

Table 2.The result of walking time threshold value （minutes）

Category / Tantile	Ideal time			Maximum limit time		
	All samples	Male	Female	All samples	Male	Female
50% percentile	8.1	8.5	8.7	11.8	10.6	11.7
70% percentile	10.4	10.5	11.1	14.0	12.8	14.5
85% percentile	12.8	12.6	13.8	16.3	15.2	17.3
90% percentile	-	-	-	17.4	16.4	18.8

4.3 A comparative analysis of the psychological feeling features of pedestrian distance and time to rail station

In this paper, by data fitting the distribution characteristic curve of an acceptable degree of access distance and time for walker can be deduced (Fig. 7 (a)). It can be seen that, according to 85% percentile, pedestrians think the acceptable limits within about 1km and the acceptable time for walking is about 12 minutes.

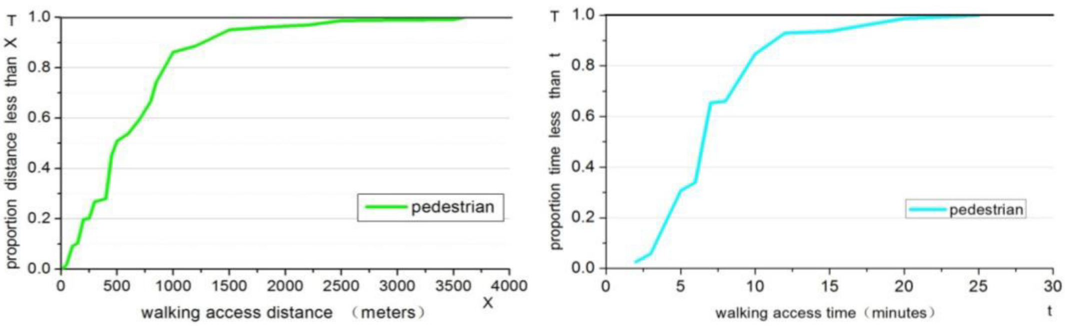

Figure 7[a] The distribution features of distance acceptability

Figure 7[b] The distribution features of time acceptability

By converting walking access time into the corresponding equivalent distance using average walking speed， as Fig.7（c）shows，the distribution features of the equivalent distance and the measured values of pedestrian distance acceptability are contrasted. As individuals' feelings about accuracy of time and distance are different, there are difference between the equivalent values of pedestrian distance and time acceptability and the measured values. Based on 85% percentile, pedestrians would accept time range within about 12 minutes. 800~1 000 meters can be estimated, depending on the results of acceptable time by the walking speed equal to 4~5 km/h, which fits to the walking distance limits value of 1km. When the distance is less than 500 meters, the difference between the perceived value and the measured value is not significant（i.e. equivalent distance which the walking time converted into using average walking speed）.While the distance is longer than 500 m and less than 1 000 m, the pedestrians tend to overestimate travel distance. The same time individuals' perceptive accuracy of time is more sensitive than to the distance.

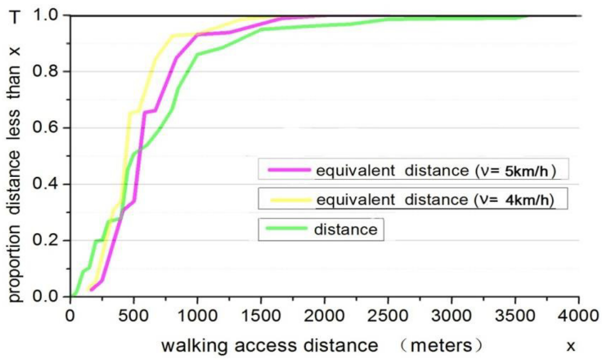

Figure 7[c] The distribution features of equivalent walking distance

5.CONCLUSIONS

From the view of pedestrians' perception and willingness, the paper conducted questionnaire survey and simulated experiment. The main conclusions are shown as follows:

1) For people walking to subway stations, the walking distance to the subway station is the most important factor, and the research shows that 84% of them think the impact as very important and people who regard it as somewhat important accounted for 16%.

2) By analysis of KLP model, the standard distance of respondents is 472 meters, and the maximum reasonable distance is 862 meters. However, the standard distance and the maximum reasonable distance for males are shorter than those for females.

3) Through the KLP model regression, the ideal access time for males and females is 8.5 minutes and 8.7 minutes, respectively, based on 50% quartile. Males can accept maximum time of about 16.4 min, and females can accept 18.8 min based on 90% quartile.

4) The research shows that the perception values of pedestrian distance and time acceptability are different from the measured values. There is also difference between individuals' feeling accuracy of time and distance. It is necessary to study these differences to revise the threshold values deeply in future.

The results of the study provide quantitative indicatives for the planning and evaluation of urban rail transit stations. Especially, the determination of the space-time threshold of access to urban rail stations can be regarded as an important basis for evaluation of land layout around urban rail stations and its scale. Due to the limited sample size in the investigation, we mainly analyzed the gender differences. Further survey would be conducted in following research.

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